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Detection of Aircraft Using Over-the-Horizon Radar

[Unclassified Title]

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Radar Techniques Branch
Radar Division

January 13, 1967

NAVAL RESEARCH LABORATORY
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NRL Report 6508

Detection of Aircraft at Very Low Altitudes Using Over-the-Horizon Radar

[Confidential Title]

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Radar Techniques Branch
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ABSTRACT
[Secret]

Tracking of an aircraft flying at an altitude of 100 ft above the sea was accomplished over a radial range interval ranging from 1400 to 1000 naut mi by using the Project MADRE radar. Simultaneous tracking, over part of this range interval, of another aircraft at 10,000 ft illustrates the target altitude independence characteristic of over-the-horizon techniques.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem R02-23G
Project MIPR (30-602)67-C-0070,

Manuscript submitted November 4, 1966.

DETECTION OF AIRCRAFT AT VERY LOW ALTITUDES USING OVER-THE-HORIZON RADAR
[Confidential Title]

INTRODUCTION

The feasibility of over-the-horizon (OTH) aircraft detection has been extensively reported (1-7). In these previous tests the aircraft were permitted to operate at their normal cruising altitude of 9000 to 40,000 ft depending on the aircraft type. There are many reasons for being able to make detections at altitudes approaching zero. To demonstrate that OTH radar detection capability is truly independent of altitude, arrangements were made with NAS Patuxent River, Maryland, to deploy a P3A aircraft along a radial path from 1400 naut mi to about 1000 naut mi on a bearing of 074° true from the radar site at Chesapeake Beach, Maryland. Altitude for this 400-naut mi portion of the flight was to be 100 ft. A test altitude of 100 ft was chosen because it was felt that a lower altitude would be unduly hazardous and yet 100 ft would be sufficiently low to demonstrate the capability. It is firmly believed that given sufficient speed radial to the radar site, surface vehicles would be easily observable.

ANALYSIS OF RANGE-TIME TRACK

The equipment used in this demonstration is a coherent, pulse doppler, high-frequency radar using the refractive properties of the ionosphere to provide beyond line-of-sight (over-the-horizon) coverage. It is described more fully in Refs. 8-14. Although the test portion of this demonstration encompassed only ranges from 1400 to 1000 naut mi, the target was actually acquired at a somewhat greater range of approximately 2075 naut mi shortly after takeoff and before reaching cruise altitude (22,000 ft). Except for periods during which the radar was not operating (to allow changing the frequency, taking backscatter pictures, etc.), the P3A aircraft was tracked continuously from acquisition at 2075 naut mi, through its low-level exercises, and finally to a ground range of 740 naut mi. Figure 1 is a computer-generated range-time plot showing the apparent ground range versus time calculated on the basis of radar (or slant) range and ionospheric scalings obtained from Ft. Belvoir, Virginia. An apparent ground range is calculated for each radar data point taken during real-time operation and is displayed on the plot as a circle, square, or diamond depending on whether the ionospheric layer used in the calculations was the F_2, F_1, or E layers, respectively. In the interest of clarity, only those paths actually in use are shown in Fig. 1. The actual flight path as reported by the navigator is shown as a solid line with crosses indicating the navigator's position determinations.

In the range segment between 1850 and 2075 naut mi, Fig. 1 shows the data points as circles, indicating an F_2 layer propagation path. However, this is not a true F_2 path. A close examination of the launch angles and maximum useable frequencies associated with the data points at a slightly nearer range (assigned an F_1 propagation mode by the computer program) indicates that propagation via an extended F_1 mode probably continued beyond the 1850-naut mi cutoff shown in Fig. 1. Since the computer program is based on geometrical ray-tracing techniques and does not consider scattering and other phenomenon which may be especially important when operating near the maximum useable frequency (MUF), as was the case here, the computer was unable to find an F_1 path for those points beyond 1850 naut mi, although it indicated a very good path at slightly shorter range. By extrapolating on the basis of the F_2 calculations and the near-range F_1 already found, relatively good range estimates can be made to allow an extension of the F_1 data. Thus,

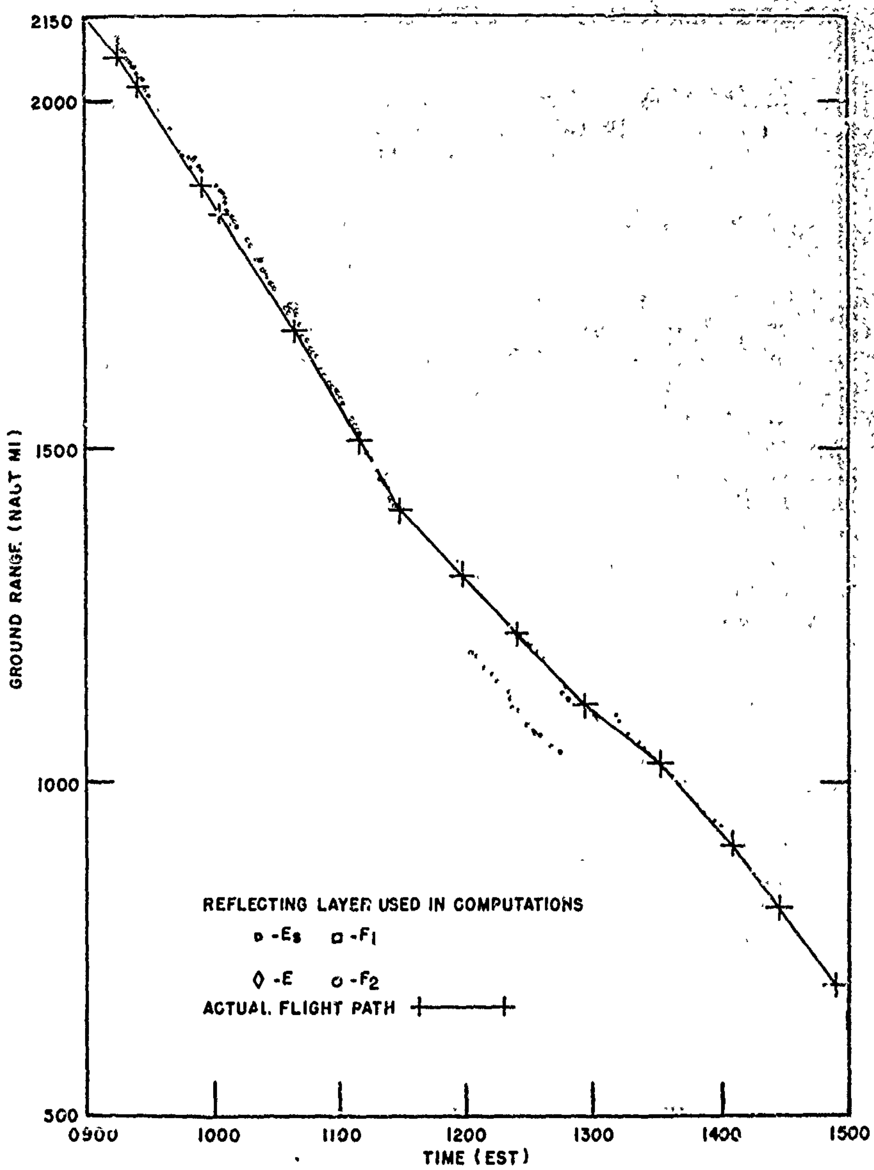

Fig. 1 - Computer-generated ground range to target, calculated from radar data taken during real-time operation on April 8, 1966

although they actually represent an F_1 propagation path, these points were based on computer calculations for the F_2 layer and therefore are shown with circles on Fig. 1.

Positive identification of the target return was made through an identifying maneuver. A change in the ground track from an inbound radial path to one 30 degrees off the radial reduced the radial component of velocity, and hence the radar doppler frequency, by a factor of cosine 30° (0.866). This maneuver proved quite helpful in distinguishing between the test aircraft and other aircraft which by chance were at approximately the same range and radial velocity. One particularly interesting example occurred while the observer was attempting to reacquire the target after the radar had been inoperable for 30 min to change the operating frequency. Although the radar observer knew the approximate radar range and radial velocity to expect of the target aircraft, a close examination of the range-time plot shown in Fig. 1 indicates that for about 30 min after radar operation was resumed, the radar observer was probably following a target other than the intended low-level P3A. This target was about 100 naut mi closer to the radar site and moving inbound at about the same rate as the P3A aircraft. (This range differential of 100 naut mi may appear quite large, but at the extended ranges involved it only represents about 8 percent.)

The altitude of this target was assumed to be approximately 10,000 ft since essentially all aircraft with the speed indicated do operate at this cruise altitude. After tracking this target for several minutes, the radar observer noticed a second target on the display which could also be the P3A. Both targets were then tracked for several minutes until the test aircraft executed an identifying maneuver, causing a sudden decrease in the second target's measured velocity. Identification was considered confirmed, and tracking of the first target was discontinued. Note that this identification procedure involves use of a skin track only, whereas early methods entailed use of beacons, transponders, etc.

ANALYSIS OF TEMPORAL BEHAVIOR

Considerable interest in the fading patterns of various aircraft targets has been generated because of the possibility of determining the altitude of these targets on the basis of the structure of their fading patterns (6). Fading patterns for the low-level P3A (altitude 100 ft) and its companion (altitude approximately 10,000 ft) have been examined but do not show any obvious structural dissimilarities. However, through use of correlation techniques to provide a knowledge of the frequency structure of the patterns, additional information may be extracted which could reveal periodicities that are a function of the aircraft's altitude. Additional work along these lines is in progress.

CONCLUSION

The tracking of low-flying aircraft has been successfully demonstrated and the detection capability is shown to be essentially the same as for flights at other altitudes.

RECOMMENDATIONS FOR CONTINUED INVESTIGATIONS

It is recommended that the following ten studies be pursued in a continuing program of over-the-horizon (OTH) aircraft detection:

1. Determine the dependence of detection capability on ionospheric conditions. Such a study may include the extent and correlation in space and in time of propagation outages. Included should be such effects as:

a. lossy ionospheric conditions, such as those caused by disturbances, magnetic storms, etc.,

b. unstable ionosphere resulting in poor correlation or poor clutter rejection. This condition may be confused with the effects of operating on frequencies which are equal to or greater than the maximum usable frequency (MUF). Therefore, a procedure for differentiating the two effects should be developed.

2. Determine with improved precision the accuracy of range and azimuth determination.

3. Determine if a correlation can be found between the temporal behavior of echoes and altitude, speed, or ionospheric condition.

4. Determine the accuracy of basic ionospheric predictions as reflected in real-time operations.

5. Study the apparent target reflecting area to determine its correlation with aircraft type and backscatter echoes. A by-product will be the ability to compute output signal-to-noise ratios for a given set of conditions.

6. Determine if the doppler frequencies of targets are affected by the range of detection.

7. Further studies of multiple targets to confirm the doppler resolution and target signature data already acquired.

8. Occasional multihop detections occur during the normal pursuit of one-hop surveillance. These should be further analyzed to determine the relationship between one-hop and two-hop losses.

9. Further evaluation of the frequency band occupancy problem.

10. Continued experimentation to determine the relationship between line-of-sight and OTH cross section.

Each of the above may be helpful in revealing insufficiency of equipment design and possibilities for improvement.

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Radar Signals						
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Ionospheric Propagation						
Radar Cross Sections						
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3. High frequency transmitters

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